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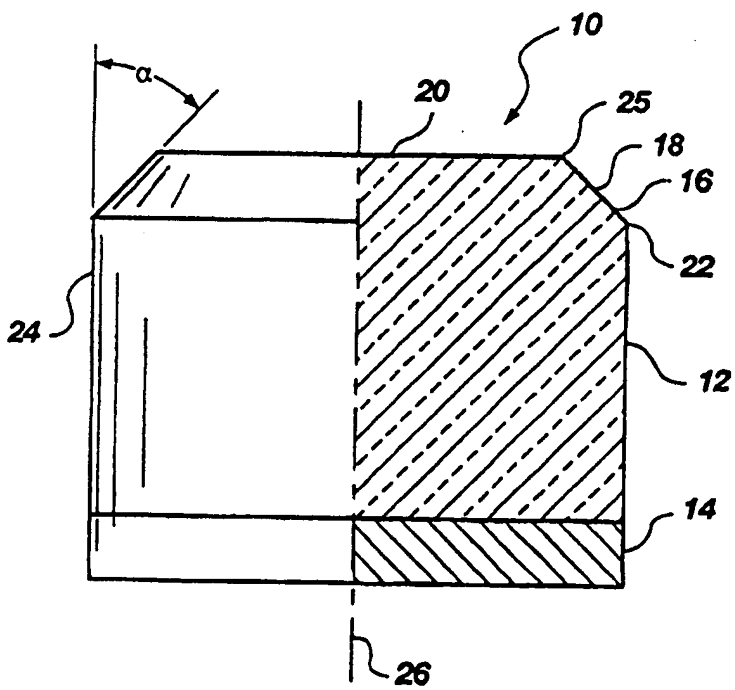
(57) Abstract

A diamond cutting element (10) for use on an earth boring drill bit, such as a rotary drag bit. The cutting element is predominantly comprised of a diamond cutting structure (12) attached to either a reduced-volume substrate (14) or directly to a bit body, optionnally using a carrier structure mounted to the bit body. With such a configuration, stress between dissimilar materials, such as the substrate and the cutting structure, is reduced or entirely eliminated. Moreover, only the diamond cutting structure contacts the formation during drilling resulting in lower friction, lower temperatures and lower wear rates of the cutting elements. The diamond cutting structure may also be polished and include one or more internal passageways that extend into the diamond through which fluids may be passed to transfer heat from the cutting element during drilling.



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PREDOMINANTLY DIAMOND CUTTING STRUCTURES FOR EARTH BORING

BACKGROUND

Field of the Invention. The present invention relates generally to superabrasive cutting elements, and more specifically to polycrystalline diamond compact cutting elements, comprised substantially of diamond optionally bonded to a reduced-mass supporting substrate.

State of the Art. Fixed-cutter rotary drag bits have been employed in subterranean drilling for many decades, and various sizes, shapes and patterns of natural and synthetic diamonds have been used on drag bit crowns as cutting elements. Rotary drag-type drill bits are typically comprised of a bit body having a shank for connection to a drill string and encompassing an inner channel for supplying drilling fluid to the face of the bit through nozzles or other apertures. Drag bits may be cast and/or machined from metal, typically steel, or may be formed of a powder metal (typically WC) infiltrated at high temperatures with a liquified (typically copper-based) binder material to form a matrix. It is also contemplated that such bits may be formed with so-called layered manufacturing technology, as disclosed in U.S. Patent 5,433,280, assigned to the assignee of the present invention and incorporated herein by this reference.

The bit body typically carries a plurality of cutting elements mounted directly on the bit body or on a carrier element. Cutting elements may be secured to the bit by preliminary bonding to a carrier element, such as a stud, post, or cylinder, which in turn is inserted into a pocket, sachet, recess or other aperture in the face of the bit and mechanically or metallurgically secured thereto. Polycrystalline diamond compact (PDC) cutting elements may be brazed directly to a matrix-type bit or to a pre-placed carrier element after furnacing, or even be bonded into the bit body during the furnacing process. It has also been suggested that PDC cutting elements may be adhesively bonded to the bit face or to a carrier element.

For over a decade, it has been possible to process diamond particles into larger disc shapes. The discs, or diamond tables, are typically formed of sintered polycrystalline diamond, the resulting structure being free-standing or bonded to a

tungsten carbide layer during formation. A typical PDC diamond table/WC substrate cutting element structure is formed by placing a disc-shaped cemented carbide substrate including a metal binder such as cobalt into a container or cartridge of an ultra-high pressure press with a layer of diamond crystals or grains loaded into the cartridge adjacent one face of the substrate. A number of such cartridges are typically loaded into a press. The substrates and adjacent diamond crystal layers are then compressed under ultra-high temperature and pressure conditions. These conditions cause the metal binder from the substrate body to become liquid and sweep from the region behind the substrate face next to the diamond layer through the diamond grains to form the polycrystalline diamond structure. As a result, the diamond grains become mutually bonded to form a diamond table over the substrate face which is bonded to the substrate face. The spaces in the diamond table between the diamond-to-diamond bonds are filled with residual metal binder. It is also possible to form free-standing (no substrate) polycrystalline or monocrystalline diamond structures, providing another source of binder is employed, as is known in the art. For example, powdered binder may be intermixed with the diamond grains.

A so-called thermally stable PDC product (commonly termed a TSP) may be formed by leaching out the metal in the diamond table. Alternatively, silicon, which possesses a coefficient of thermal expansion similar to that of diamond, may be used to bond diamond particles to produce a Si-bonded TSP. TSPs are capable of enduring higher temperatures (on the order of 1200°C) without degradation in comparison to normal PDCs, which experience thermal degradation upon exposure to temperatures of about 750-800°C. TSPs are typically free-standing (e.g., without a substrate), but may be formed on a substrate. TSPs may also be coated with a single- or multi-layer metal coating to enhance bonding of the TSP to a matrix-body bit face.

Any substrate incorporated in the cutting element must sufficiently support the diamond table to curtail bending of the diamond or other superabrasive table attributable to the loading of the cutting element by the formation. Any measurable bending may cause fracture or even delamination of the diamond table from the substrate. It is believed that such degradation of the cutting element is due at least in part to lack of sufficient stiffness of the cutting element so that, when

encountering the formation, the diamond table actually flexes due to lack of sufficient rigidity or stiffness. As diamond has an extremely low strain rate to failure, only a small amount of flex can initiate fracture.

PDC cutting elements, with their large diamond tables (usually of circular, semi-circular or tombstone shape) have provided drag bit designers with a wide variety of potential cutter deployments and orientations, crown configurations, nozzle placements and other design alternatives not previously possible with the smaller natural diamond and polyhedral, unbacked synthetic diamonds (usually TSPs) traditionally employed in drag bits. These PDC cutting elements, with their large diamond tables extending in two dimensions substantially transverse to the direction of cut have, with various bit designs, achieved outstanding advances in drilling efficiency and rate of penetration (ROP) when employed in soft to medium hardness formations, and the larger cutter dimensions and attendant greater protrusion or extension above the bit crown have afforded the opportunity for greatly improved bit hydraulics for cutter lubrication and cooling and formation debris removal.

Since the early days of PDC use on drill bits, however, it has been apparent that PDCs suffer thermal degradation at the high temperatures generated by the frictional abrasive contact of the PDC cutting edge with the formation as the bit rotates and weight is applied to the drill string on which the bit is mounted. Such degradation leads to premature dulling of the PDC cutting edge, and even gross failure of the PDC cutting element assembly. Improved feed stock and fabrication techniques have raised the thermal tolerance of PDCs to some degree. As noted above, there has been developed a subcategory of PDCs known as thermally stable products, or TSPs, which retain their physical integrity to temperatures approaching 1200°C. TSPs may be infiltrated into matrix body drill bits at the time of bit furnacing, rather than being attached at a later time, as with non-thermally stable PDCs. However, even TSPs suffer from thermal degradation during cutting of the formation as the drill bit advances the wellbore.

While the prior art has focused on problems associated with the degradation of the diamond layer or table, heating of the cutting element substrate (typically tungsten carbide) from the drilling operation is also detrimental to cutting element performance. Heat checking of the substrate, typically caused in one form by

alternative heating and quenching of the cutting elements as the drill bit bounces on the bottom of the borehole and drilling fluid intermittently contacts the cutting elements at the cutting edges, can initiate more severe substrate cracking which, in turn, can propagate cracking of the diamond table.

A variety of attempts have been made to cool and clean PDC cutting elements during the drill operation by flushing the cutting elements with drilling fluid, or "mud," pumped down the drill string and through nozzles or other orifices on the face of the bit. The flow of drilling mud removes formation cuttings and other debris from the face of the bit and generally radially outwardly to the bit gage, up the junk slots and into the wellbore annulus between the drill string and the wall of the wellbore to the surface, where the debris is removed, the mud screened and reconditioned with additives and again pumped down the drill string. It is known in the art to direct drilling mud flow across the face of a series of cutting elements (U.S. Patent 4,452,324 to Jürgens); to direct mud flow from a nozzle toward the face of a single cutting element (U.S. Patent 4,303,136 to Ball); and to direct flow from a nozzle to a single cutting element at a specific orientation (U.S. Patent 4,913,244 to Trujillo). It has also been proposed to direct mud flow through the face of a PDC cutting element from internal passage extending from the interior of the drill bit through the carrier element and out an aperture in the face of the cutting element (U.S. Patent 4,606,418 to Thompson).

It has also been proposed, in U.S. Patent 4,852,671 to Southland, to direct drilling mud flow through a passage in a stud supporting a PDC to a relief between the pair of cutting points in the formation-contacting zone of a disc-shaped PDC cutting element to improve the cooling and cleaning of the cutting elements. Moreover, in U.S. Patent 5,316,095 to Tibbitts, the cutting element is cooled with drilling fluid via a plurality of internal channels having outlets adjacent the peripheral cutting edge of the diamond cutting element.

In addition to degradation of the cutting element due to thermal effects, the interface of the diamond table with the substrate (typically tungsten carbide, or WC) is subject to high residual shear stresses arising from formation of the cutting element, as after cooling the differing bulk moduli and coefficients of thermal expansion of the diamond and substrate material result in thermally-induced stresses. In addition, finite element analysis (FEA) has demonstrated that high tensile stresses

exist in a localized region in the outer cylindrical substrate surface and internally in the WC substrate. Both of these phenomena are deleterious to the life of the cutting element during drilling operations, as the stresses, when augmented by stresses attributable to the loading of the cutting element by the formation, may cause spalling, fracture or even delamination of the diamond table from the substrate.

In addition to the foregoing shortcomings, state of the art PDCs often lack sufficient diamond volume to cut highly abrasive formations, as the thickness of the diamond table is limited due to the inability of a relatively thick diamond table to adequately bond to the substrate. Further, as the diamond table wears in the prior art cutting elements, more and more of the substrate material becomes exposed to the formation, increasing the so-called "wear flat" area behind the cutting edge of the diamond table and resulting in less-efficient cutting for a given weight on bit (WOB).

Moreover, the frictional coefficient of diamond in contact with rock is much lower than that of the substrate material. Thus, as the wear flat increases, friction and frictionally-induced heating of the cutting element increase.

SUMMARY OF THE INVENTION

In contrast to the prior art, the cutting element of the present invention is comprised predominantly of diamond with a reduced size substrate or, in some embodiments with no substrate. That is, the diamond cutting structure (commonly referred to as a diamond table) volume exceeds the volume of the substrate so that a substantially all-diamond cutting element is presented to the formation. In several of the preferred embodiments, the substrate is completely eliminated such that only the diamond cutting structure and, optionally, a carrier element are necessary for mounting the cutting structure to a drill bit. By removing, if not eliminating the substrate, stresses between dissimilar materials can be substantially reduced and heat transfer from the diamond enhanced.

It is preferred that the diamond table of the cutting element according to the present invention be quite robust in the vicinity of the cutting face, in comparison to prior art structures. For example, it is preferred that the diamond table be at least 0.381 centimeter (0.150 inch) thick, measured with respect to the longitudinal axis of the cutting element, at least in the vicinity of the cutting edge. Even thicker

diamond tables are contemplated as within the scope of the invention, and may be preferred for use in some formations.

The use of large volumes or masses of diamond in the cutting element, particularly adjacent the formation being cut, provides for better heat transfer and provides more convective area for same. In addition, frictional forces are minimized in comparison to prior art cutting elements having substrates which quickly contact the formation due to wear flat development, minimizing heat generation and lowering required bit torque. Further, the presence of an all-diamond volume adjacent and to the rear of the cutting edge avoids the diamond/substrate interface stresses present during loading of prior art cutting elements. In addition, elimination of the carbide substrate minimizes residual stresses within the cutting element, producing a substantially "zero residual stress" cutting structure in a macro sense, the crystalline bond micro-stresses being substantially uniform and offsetting throughout the structure.

In some preferred embodiments, the cutting element of the invention comprises a solid, imperforate volume of diamond, which may be formed with or without an associated substrate element.

In various preferred embodiments, the cutting element of the present invention comprises a substantially hollow, cup-shaped cutting structure (i.e., diamond table) of circular, rectangular or other suitable cross-section comprising a PDC, TSP, or other superabrasive material bonded to a supporting substrate. Such a configuration helps transfer heat generated during the drilling process away from the cutting structure, while providing the required structural support necessary for the cutting element.

Because of the size of the diamond cutting structure and the high forces and stresses placed on the cutting structure during drilling, it may be desirable to chamfer, bevel, or taper the cutting edge of the cutting structure. That is, for a cylindrical cutting structure, to provide a frustoconical-inwardly tapered portion extending from a location on the periphery of the cutting structure to the cutting face. More than one chamfer or taper may also be used to provide additional support for the cutting edge and cutting face of the cutting structure. See, for example, U.S. Patent 5,437,343, assigned to the assignee of the present invention and incorporated herein by this reference. The angle of such a taper or chamfer

may be quite varied to either extreme, ranging from about 10 degrees (10°) to approximately 80 degrees (80°) with regard to the longitudinal axis of the cutting element, or to the sidewall if it parallels the axis. The longitudinal axis is defined as the axis extending generally transversely to the direction of cut, and transverse to the cutting face in the case of a cylindrical cutting element. Polishing exterior surfaces of the cutting structure may also help reduce friction during drilling and thus thermally induced stresses. U.S. Patent 5,447,208, assigned to the assignee of the present invention, discloses cutting elements of reduced surface roughness and is hereby incorporated by this reference.

In some embodiments, the cutting element does include a substrate. The substrate, however, is relatively small in comparison to the size of the diamond cutting structure. The substrate may be substantially planar on both its front and back sides or include a raised portion or portions to mate with a recess or recesses formed in the mating end of the diamond cutting structure and/or a carrier element.

In several of the preferred embodiments, the diamond cutting structure includes several cavities formed therein extending longitudinally along a length of the diamond cutting structure. The cavities may be in the form of pie segment-shaped recesses or circular bores and preferably extend from a distal or trailing end of the cutting structure to a location behind the cutting face. Moreover, these internal cavities, passageways, or channels may then be placed in fluid communication with a carrier element on a bit body such that fluid may be passed from the bit body interior through the carrier to the interior of the cutting structure.

Other recesses may be formed in the distal end of the cutting structure to accommodate mating with a post, stud, or other carrier element which is formed or attached by means known in the art to the face of the rotary drag bit. This mating arrangement may be in the form of a male-female interconnection where the carrier extends into the recessed portion of the cutting structure such that the cutting structure "caps" the carrier, or where the carrier provides a circumferential sleeve to fit around the cutting structure. In addition, the fit between the carrier and the cutting structure may form one or more gaps or voids, also termed chambers, such that a fluid passed through internal channels in the carrier to these voids or gaps can cool the cutting structure during drilling.

In another preferred embodiment of the invention, an attachment ring comprised of a hard material such as tungsten carbide may be bonded to the distal end of the cutting structure by means known in the art, such as brazing. This attachment ring could then be attached to the surface of a bit face or a carrier element. Similarly, an attachment sleeve could be attached to the outer perimeter of the cutting structure. For an attachment sleeve arrangement, the cutting structure could be mushroom-shaped such that the sleeve extends over the stem of the cutting structure and up to its cap. In this way, the sleeve would be shielded from the formation by the cutting structure during drilling.

While the preferred embodiments employ a substantially planar cutting face with a generally cylindrical outer surface, other partial-,half- or non-circular configurations such as so-called "tombstone" cutters and other shapes, including oval, square, rectangular triangular or other polygonal shapes are also contemplated. Additionally, other substantially planar diamond cutting faces, such as ridged, convex, concave, and combinations thereof, may also benefit from a cutter according to the present invention. The term "substantially planar" as used herein is intended only to describe a cutting face extending in two dimensions, and not as limiting the topography or shape of the cutting face itself.

It is believed that a major aspect of the present invention, regardless of the specific cutter shape, is the volume of the diamond cutting structure in absolute terms and relative to that of the substrate. In addition, recessed portion or portions formed in the cutting structure to help cool the diamond cutter and provide a means for attachment of the diamond cutter are also significant. An all or substantially-all diamond cutter having a diamond table of increased depth in contact with a formation will wear in a vertical direction less than state-of-the-art cutting elements employing a thin diamond table of the same composition and on a conventional, larger-volume substrate, the reduced wear being a function of the greater surface area of diamond in contact with the formation provided by the greater diamond volume. Further, cutting elements of the invention may be cooled more easily, will stay sharper for a longer period of time, and will be less susceptible to stresses encountered during drilling in comparison to prior art cutting elements.

These and other advantages of the present invention, will become apparent from the following detailed description, the accompanying drawings, and the appended claims.

It should be noted that the term "diamond," "polycrystalline diamond," or "PDC" as used in the specification and claims herein shall be interpreted as including all diamond or diamond-like cutting elements having a hardness generally similar to or approaching the hardness of a natural diamond, including without limitation PDCs, TSPs, diamond films, cubic boron nitride, and combinations thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a partial cross-sectional view of a first embodiment of a cutting element in accordance with the present invention;

FIG. 1B is a partial cross-sectional view of a prior art cutting element;

FIG. 2 is a partial cross-sectional view of a second embodiment of a cutting element in accordance with the present invention;

FIG. 2A is a partial cross-sectional view of a variation of the second embodiment of the cutting element of FIG. 2;

FIG. 3 is a cross-sectional view of a third embodiment of a cutting element in accordance with the present invention;

FIG. 4 is a cross-sectional view of a fourth embodiment of a cutting element in accordance with the present invention;

FIG. 5 is a cross-sectional perspective view of a fifth embodiment of a cutting element in accordance with the present invention;

FIG. 6 is a cross-sectional perspective view of a sixth embodiment of a cutting element in accordance with the present invention;

FIG. 7 is a schematic side view of a seventh embodiment of a cutting element in accordance with the present invention;

FIG. 8 is a schematic rear view of the embodiment shown in FIG. 7; and

FIG. 9 is a typical rotary drag bit used a potential carrier or platform for PDC cutting elements such as those of the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

FIG. 1A illustrates a first embodiment of a cutting element 10 in accordance with the present invention. The cutting element 10 is comprised of a diamond cutting structure 12 (also referred to as a diamond table) preferably made from polycrystalline diamond, and a substrate 14 formed of a cemented carbide such as tungsten carbide, or other suitable material such as a ceramic or ceramet. In lieu of polycrystalline diamond, other superabrasive materials may be employed, such as diamond films, cubic boron nitride and a structure predicted in the literature as C_3N_4 in the literature as being equivalent to known superabrasive materials. The cutting element 10 is shown as having a generally cylindrical perimeter with a frustoconical inward taper 16 at the proximal end 18. This taper 16 may be necessary to reduce the likelihood of the cutting face 20 from being damaged by impact during drilling, and to direct forces encountered during drilling toward the center of the diamond cutting structure 12. The angle α may range preferably from approximately ten degrees (10°) to 80 degrees (80°) with respect to sidewall 24, which in this instance lies parallel to longitudinal axis 26, and the taper 16 may extend the entire length of the diamond cutting structure 12. A small chamfer or radius may also be employed at edge 22 and/or at edge 25 at the boundaries of taper 16.

The diamond cutting structure 12 is formed to substrate 14 during fabrication, as known in the art. As illustrated, the volume of the diamond cutting structure 12 is at least as great and preferably greater, than the volume of the substrate 14. Such a configuration, particularly when manifested as shown by a diamond table of substantial depth in the longitudinal direction (e.g., substantially transverse to the direction of cut), keeps the substrate 14 from contacting the formation as the diamond cutting structure 12 wears. Thus, a maximum amount of diamond is exposed to the formation for cutting purposes, and provides the previously enumerated advantages. Diamond cutting structure 12, while shown as a cylinder, may in fact comprise any configuration and cross-sectional shape. Moreover, the diamond volume may be uniform, e.g., fabricated of a single diamond feedstock of a particular size or size range, or may be formed of different feedstock of different sizes, or of preformed diamond structures sintered or otherwise bonded together to define the cutting structure 12. Structure 12 may also

be formed as layers of different (structure, size, wear resistance, etc.) diamond materials, or as strips, rings or other segments of different materials. In such a manner, load capacity and wear resistance may be altered as desired or required by the nature of the formation to be drilled.

In comparison, a prior art cutting element 30 as shown in FIG. 1B is comprised of a diamond cutting structure or table 32 that usually has a depth much less than the size of the supporting substrate 34. In reality, the thickness of diamond table 32 is far less than shown relative to the substrate, on the order of 0.076 centimeter (0.030 inch) or less, although diamond tables of up to 0.300 centimeter (0.118 inch) have been proposed. See U.S. Patent 4,792,001. Even in the case of an extremely thick conventional diamond table, as diamond wears from the cutting element 30, the supporting substrate 34 comes in contact with the formation being drilled, forming a wear flat which quickly increases in area, reduces the cutting efficiency of the drill bit, increases friction and frictionally-induced heating of the cutting element. Further, the thin diamond tables of the prior art result in a relatively high thermal gradient across the diamond table in comparison to the cutting elements of the invention. Moreover, because the substrate 34 is substantially exposed to the heat associating with drilling, greater thermal stresses exist between the cutting structure 32 and the substrate 34 as compared to the cutting elements of the present invention. Chamfers such as chamfer 36 have been incorporated into diamond cutting elements, but have been of insignificant width and are primarily used to interrupt the otherwise 90° cutting edge 39 between the cutting face 38 and the outer surface 40 to protect the cutting edge from impact-induced damage before substantial cutting element wear occurs.

As shown in FIG. 2, a second embodiment of a cutting element 50 is illustrated. In this embodiment, however, the diamond cutting structure 52 defines a recess 54 at its distal end 56 having an inner surface 53. The recess 54 is shown as being substantially cylindrical in nature and concentric with the rest of the cutting element 50. The substrate 58 includes a raised portion 60 sized and shaped to be matable with the recess 54 to form a male-female-type interconnection which provides high shear strength at the diamond table/substrate interface. The substrate 58 and the diamond cutting structure 52 are bonded together during formation of the cutting structure 52 as known in the art. The illustrated structure is practical,

despite the differences in coefficients of thermal expansion between the two materials, due to the large mass or volume of diamond which promotes heat transfer and reduces the temperature gradient across the length of the cutting element, minimizing stresses at the table/substrate interface.

FIG. 2A depicts a variation of the structure of FIG. 2. In this case, cutting element 150 includes a diamond or other superabrasive cutting structure 152 which extends into a recess 154 in cup-shaped substrate 158 to form a male-female-type interconnection.

Referring now to FIG. 3, another embodiment of a cutting element 70 is shown. The cutting element 70 is comprised of a cup-shaped diamond cutting structure 72 and a carrier 74. The carrier 74 (commonly referred to as a stud or post) includes a support member 76 and an attachment member 78 depending from the support member 76. The attachment member 78 (as shown) is of a generally cylindrical configuration. The diamond cutting structure 72 has a substantially cylindrical outer perimeter 80 and a cutting face 82, both of which may be polished to help reduce friction. A large chamfer 83 (as shown) may be employed on cutting face 82. The cutting structure 72 also includes a recess 84 formed in its distal end 86 sized and shaped to snugly receive the attachment member 78. As illustrated, the diamond cutting structure 72 basically fits like a cap over the attachment member 78. The diamond cutting structure 72 may be bonded or brazed as shown at 88, or even shrink fit to the attachment member 78 by methods known in the art. It is also contemplated that element 88 be a carbide sleeve to accommodate the braze employed to secure the cutting element to the bit. A carbide sleeve 88 might completely, or only partially, encompass diamond structure 78. It is further contemplated that element 88 be a single or multi-layer metal coating to facilitate in-furnace bonding to the bit body during formation, such coating being disclosed in U.S. Patent 5,049,164, assigned to the assignee of the present invention and incorporated herein by this reference. It is contemplated that attachment member 78 may be non-cylindrical, or even non-symmetrical, and that the recess 84 of cutting structure may be formed to mate therewith. As alluded to previously, the present invention is geometry-independent, and is thus free of design limitations other than those imposed by the designer to effectuate a particular purpose associated with the cutting performance or mounting regime of the cutting element.

Similar to the embodiment shown in FIG. 3, FIG. 4 illustrates an additional use for a gap or void 92 formed between the diamond cutting structure 94 and the attachment member 96 of the cutting element 90. The gap 92 is a result of a frustoconical inward taper 98 at the proximal end 100 of the attachment member 96. Because of its cylindrical nature, the gap 90 forms an annular chamber between the cutting structure 94 and the attachment member 96. The carrier 102 is formed with channels 104 and 106 that extend through the support member 108 and through the attachment member 96 to be in fluid contact with the gap or chamber 92. A fluid, such as drilling fluid, can then be passed through the channel 104, into the gap 92 to promote heat transfer from the cutting structure, and circulated out through channel 106. It is also contemplated that the channels may comprise grooves formed on the exterior of attachment member 96 or on the interior of cutting structure 94, in either case communicating with passages extending through support member 108. It is further contemplated that a single channel 104 to supply fluid may be employed extending into cutting structure 94, and that an aperture be formed in cutting structure 94 as shown in broken lines at 95 or 97 for fluid to exit after heat is transferred to it. Alternatively, channel 106 may exit from the bit body (support member 108) as shown in broken lines at 107, rather than returning to the interior. Another alternative is to employ a channel such as 106 to supply fluid, and configure channel 104 to exit the bit body (support member 108) as shown at 109. Additional fluid-type cutting element cooling arrangements are disclosed in U.S. Patent 5,316,095, assigned to the assignee of the present invention and incorporated herein by this reference.

FIG. 5 shows an alternate embodiment of a cutting element 110. In this embodiment, the cutting element 110 includes a substantially cylindrical cutting structure 112 and an attachment sleeve 114. At the cutting face 116, the cutting structure 112 has a diameter greater than its diameter at the location of the sleeve 114. The sleeve 114 is sized and shaped to snugly fit over the portion 118 of the cutting structure 112 having a reduced circumference or periphery 111. In this manner, the cutting face 116 extends over the proximal end 120 of the sleeve 114 so that, due to the thickness or depth of the cutting face 116, the sleeve 114 does not come into cutting contact with the formation. It is contemplated that sleeve 114 would preferably include an expansion split or slit 115 to accommodate thermally-

induced expansion and contraction and the differences in CTE between the superabrasive and sleeve materials. It is also contemplated that the sleeve 114 be substantially full-length, as shown, or of an abbreviated length, as well as of any suitable thickness. Perforated sleeves, and helical sleeves, as well as those of other configurations, are also contemplated.

The cutting structure 112 is also formed with a plurality of cavities or recesses 122 longitudinally extending from a distal end 124 into the cutting structure 112. The recesses 112 help to direct heat generated during drilling along the fins 126 and away from the cutting face 116, and may be used to contain a stationary or flowing heat-transfer fluid. Moreover, the circumferentially outer portion of distal end 124 may be deleted, sleeve 114 then directly contacting the outer edges of fins 126 as shown in broken lines.

In a similar configuration, the cutting element 130 shown in FIG. 6 includes a plurality of pie-segment or wedge-shaped cavities 132 extending into the cutting structure 134. The distal end 136 of the fins 138, however, formed by the cavities 132 is recessed into the distal end 140 of the cutting structure 134. Being recessed, the cutting structure 134 can then be attached to (placed over) a carrier element 142 having an attachment member 144. An attachment ring 146 may optionally be bonded during cutter fabrication to the distal end 140 of the cutting structure 134 to, in turn, be bonded as by brazing to the carrier element 142.

The embodiments shown in FIGS. 7 and 8 illustrate an alternate configuration to that of FIG. 5. That is, the cutting structure 152 of the cutting element 150 may comprise many different configurations without departing from the scope of the invention. For example, the cutting structure 152 may be mushroom-shaped having a stem 154 and a cap 156. The cap 156 includes a frustoconical inward taper 158 proximate a cutting face 160 and is at least as long as the stem 154. Such a cutting structure 152 could then be mounted to a sleeve, such as sleeve 114 shown in FIG. 5, or to a ring-shaped attachment member of a carrier element.

FIGS. 7 and 8 also illustrate that many different sizes and shapes of recesses or cavities 162 and 164 may be incorporated into the cutting structure. For example, bores 162 and 164 are of different cross-sectional size and shape than the cavities 122 and 132 of FIGS. 5 and 6, respectively. Moreover, as specifically shown in FIG. 7, the depth of the recesses 162 and 164 may vary. Such cavities

162 and 164 could also be placed in fluid communication with each other and/or a carrier element, such as carrier 102 in FIG. 4. A carrier 180 having a recess 182 in its proximal end (shown in broken lines) may be employed with cutting element 150.

The previously-described diamond cutting structures have been depicted as comprising single-piece diamond volumes or masses. It should be noted that this is not a requirement of the invention and, for example, cutting face 82 and perimeter 80 of cutting element 70 (FIG. 3) may be separately formed as shown at broken line 81 and later combined. Similarly, cutting face portion 116 and trailing portion 118 of cutting element 110 (FIG. 5) may be separately formed as shown at broken line 117, for ease of manufacture. The other embodiments of the invention may similarly be formed in two or more components of superabrasive material, and subsequently combined to define the cutting element or a portion thereof. Diamond structures may be bonded to each other in ultra-high pressure presses, as those used to form the separate components themselves, or metallurgical bonds may be employed where acceptable, such as when shear stresses are negligible or other mechanical structure accommodates such stresses.

As shown in FIG. 9, the various cutting elements, such as element 10, described herein are contemplated as being adaptable to any rotary-type drill bit, such as a typical rotary-drag bit 170. As shown, the bit 170 has a face 172 at a distal end 174 to which the cutting elements 10 are attached, and a threaded attachment structure 176 at a proximal end 178 for attachment to a drill string as known in the art.

As alluded to previously, those skilled in the art will appreciate that channels or passageways may be formed in the diamond material of the cutting elements, in the substrate material, or partially formed in both. Also, the substrate material may be machined, while the diamond material may be etched or electro-discharge machined (EDM), or ground on a diamond wheel. Fluid may be provided to the channels or passageways individually, or from a central feed point via a manifold arrangement. The structure may also include a carrier element having a fluid feed passage or passages for the channels or passageways.

It should be understood that the present invention is not limited to diamond cutters commercially available on the market, but may also be easily adapted to

cutting elements comprising a diamond film, and in fact may be especially suited for use with same due to the ease with which passageways and channels may be formed in the film, or a film deposited to define such cavities. Finally, it will be appreciated that the present invention is equally applicable to diamond cutting elements of both uniform and non-uniform thickness or depth, and of any configuration.

While the present invention is disclosed herein in terms of preferred embodiments employing PDC cutting elements, it is believed to be equally applicable to other superabrasive materials such as boron nitride, silicon nitride and diamond films.

It will be appreciated by one of ordinary skill in the art that one or more features of the illustrated embodiments may be combined with one or more features from another to form yet another combination within the scope of the invention as described and claimed herein. While certain representative embodiments and details have been shown for purposes of illustrating the invention, it will be apparent to those skilled in the art that various changes in the invention disclosed herein may be made without departing from the scope of the invention, which is defined in the appended claims. For example, various shapes and sizes of cutter substrates and diamond tables may be utilized; the angles and contours of any beveled or chamfered edges may vary; a dome-shaped or conical cutting face may be employed and the relative size and shape of any component may be changed. Moreover, the features of the present invention may be employed in half-round, quarter-round, or "tombstone" shaped or polygonal (symmetric or asymmetric) cutting elements to great advantage, and the shape of the cutting surface and the configuration of the cutting surface edge or edges of the diamond table may be varied as desired without diminishing the advantages or utility of the invention.

CLAIMS

What is claimed is:

1. A cutting element for use on a drill bit for drilling subterranean formations, comprising:

a cutting structure comprising a superabrasive material defining a two-dimensional cutting face at a proximal end, said cutting face including a cutting edge; and

wherein said cutting structure comprises a predominant volume of said cutting element.

2. The cutting element of claim 1, wherein said superabrasive cutting structure is substantially cylindrical in cross-section.

3. The cutting element of claim 1, wherein said superabrasive cutting structure has a polygonal transverse cross-section.

4. The cutting element of claim 1, wherein said superabrasive cutting structure defines an inwardly-tapered portion extending from a side of said cutting element adjacent said cutting edge and on said cutting face.

5. The cutting element of claim 1, wherein at least a portion of said cutting face is concave.

6. The cutting element of claim 1, wherein at least a portion of said cutting face is convex.

7. The cutting element of claim 1, further including a substrate of a non-superabrasive material secured to said cutting structure at a location proximate a distal end of said cutting structure.

8. The cutting element of claim 7, wherein said volume of said superabrasive cutting structure is greater than a volume of said substrate.

9. The cutting element of claim 8, wherein said substrate includes a perimeter approximating that of at least a portion of a perimeter of said superabrasive cutting structure.

10. The cutting element of claim 9, wherein either of said superabrasive cutting structure or said substrate has at least one recess formed therein defining an interior surface and adjacent the other of said superabrasive cutting structure and said substrate.

11. The cutting element of claim 10, wherein superabrasive cutting structure or said substrate includes at least one raised portion sized and shaped to substantially match said at least one recess of the other to form a male-female interconnection.

12. The cutting element of claim 1, wherein said superabrasive cutting structure includes a recess at the distal end thereof, said recess extending a distance from said distal end of said superabrasive cutting structure forward into said cutting structure.

13. The cutting element of claim 12, further including a carrier proximate said distal end of said superabrasive cutting structure.

14. The cutting element of claim 13, wherein at least a portion of said carrier extends into said at least one recess in said superabrasive cutting structure.

15. The cutting element of claim 14, wherein said superabrasive cutting structure extends laterally beyond at least a portion of said carrier.

16. The cutting element of claim 15, wherein an interface between said at least a portion of said carrier and said interior surface defines a void.

17. The cutting element of claim 16, wherein said void defines a chamber between said interior surface of said superabrasive cutting structure and said at least a portion of said carrier.

18. The cutting element of claim 17, wherein said cutting element includes at least one internal channel extending from proximate a proximal end of said carrier to proximate a distal end of said carrier.

19. The cutting element of claim 18, wherein said at least one internal channel is in fluid communication with said chamber.

20. The cutting element of claim 19, further including at least one fluid exit channel in communication with said chamber and the exterior of said cutting element.

21. The cutting element of claim 12, wherein said at least one recessed portion includes a plurality of bores.

22. The cutting element of claim 12, wherein said at least one recessed portion includes a plurality of wedge-shaped, radially-extending passageways.

23. The cutting element of claim 22, wherein said plurality of wedge-shaped passageways are defined between internal fins within said superabrasive cutting structure.

24. The cutting element of claim 23, wherein distal ends of said fins terminate within said superabrasive cutting structure.

25. The cutting element of claim 24, further including a carrier, wherein at least a portion of said carrier extends into said superabrasive cutting structure proximate said distal ends of said fins.

26. The cutting element of claim 25, further including an attachment element of a non-superabrasive material secured proximate said distal end of said superabrasive cutting structure at a first side and to said carrier at a second side.

27. The cutting element of claim 1, wherein at least a portion of an outer surface of said superabrasive cutting structure has a reduced lateral extent periphery in comparison to that of said cutting face.

28. The cutting element of claim 27, further including an attachment sleeve sized and shaped to encompass at least a portion of said reduced periphery of said superabrasive cutting structure.

29. The cutting element of claim 27, wherein said superabrasive cutting structure is mushroom-shaped, having a stem at a distal end and a cap at a proximal end.

30. The cutting element of claim 29, further including a carrier having a recessed portion formed in a proximal end, said recessed portion sized and shaped to encompass a portion of said stem of said superabrasive cutting structure to form a male-female interconnection.

31. The cutting element of claim 30, wherein said cutting structure possesses a depth of at least 0.381 centimeter (0.150 inch).

32. The cutting element of claim 31, wherein said depth is determined in a direction substantially parallel to a longitudinal axis of said cutting element.

33. The cutting element of claim 1, wherein said cutting structure is selected from one or more of the group comprising: polycrystalline diamond, diamond film, cubic boron nitride, and C_3N_4.

34. A drill bit for drilling subterranean formations, comprising:

a bit body having a proximal end defining a face and a distal end defining a connecting structure;

a plurality of cutting elements attached to said face, at least one of said cutting elements being predominantly comprised of a polycrystalline superabrasive cutting structure and defining a cutting face at a proximal end of said cutting structure, said cutting face extending in two dimensions.

35. The drill bit of claim 34, wherein said superabrasive structure is selected from one or more of the group comprising: polycrystalline diamond, diamond film, cubic boron nitride, and C_3N_4.

36. The drill bit of claim 34, wherein said cutting element includes an arcuate perimeter.

37. The drill bit of claim 34, wherein said arcuate perimeter comprises at least a segment of a circle.

38. The drill bit of claim 34, wherein said cutting element further includes a substrate having a distal end, a proximal end, and an outer surface secured to said superabrasive cutting structure proximate said substrate proximal end, said substrate having a volume less than a volume of said cutting structure.

39. The cutting element of claim 38, wherein said substrate is selected from the group comprising cemented carbides, ceramics, and ceramets.

40. The cutting element of claim 34, wherein at least a portion of said cutting structure cutting face is chamfered.

41. The cutting element of claim 40, further including at least two chamfered portions on said diamond table.

42. The cutting element of claim 40, wherein said chamfer comprises a frustoconical inward taper.

43. A method of manufacturing a cutting element for a drill bit for drilling a subterranean formation, comprising:

forming a diamond cutting structure having a proximal end and a distal end, said diamond cutting structure having at least one cavity formed in said distal end defining an inner surface;

forming an attachment structure having a distal end and a proximal end, said attachment structure having at least one raised portion on said proximal end sized and shaped to engage said distal end of said diamond cutting structure; and

attaching said diamond cutting structure to said attachment structure.

44. The method of claim 43, including forming said attachment structure from the group selected from cemented carbides, ceramics and ceramets.

45. The method of claim 43, wherein said attachment structure includes a carrier member adapted to be secured to the face of a drill bit.

46. The method of claim 43, including forming said diamond cutting structure from polycrystalline diamond.

47. The method of claim 43, including forming said at least one cavity as an internal bore.

48. The method of claim 43, including forming said at least one cavity as a wedge-shaped recess.

49. The method of claim 43, including forming said diamond cutting structure into a substantially cylindrical shape.

50. The method of claim 49, including forming said attachment structure to have a substantially cylindrical periphery.

51. The method of claim 43, further including chamfering at least a portion of said diamond cutting structure.

52. The method of claim 51, further including chamfering at least two portions of said diamond cutting structure.

53. The method of claim 43, further including attaching said cutting element to a drill bit.

54. The method of claim 43, further including forming said diamond cutting structure to be substantially rectangular in shape.

55. The method of claim 43, wherein said diamond cutting structure includes a frustoconical inward taper over at least a portion of its periphery.

56. The method of claim 43, including forming at least one chamber in said diamond cutting structure.

57. The method of claim 56, including forming at least one channel in said attachment structure in communication with said at least one chamber of said diamond cutting structure.

58. The method of claim 57, including forming at least one exit channel in said cutting element in communication with said chamber and the exterior of said cutting element.

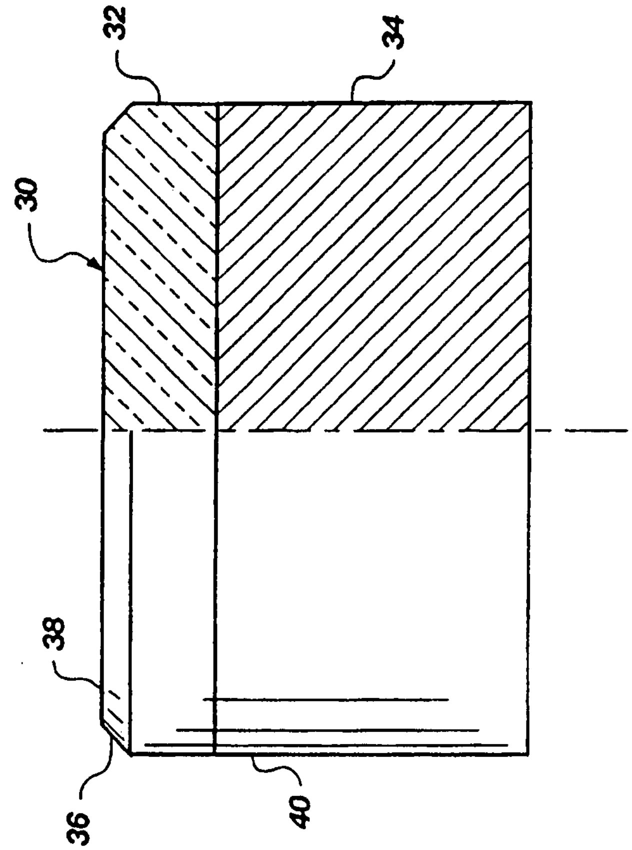

Fig. 1B
(PRIOR ART)

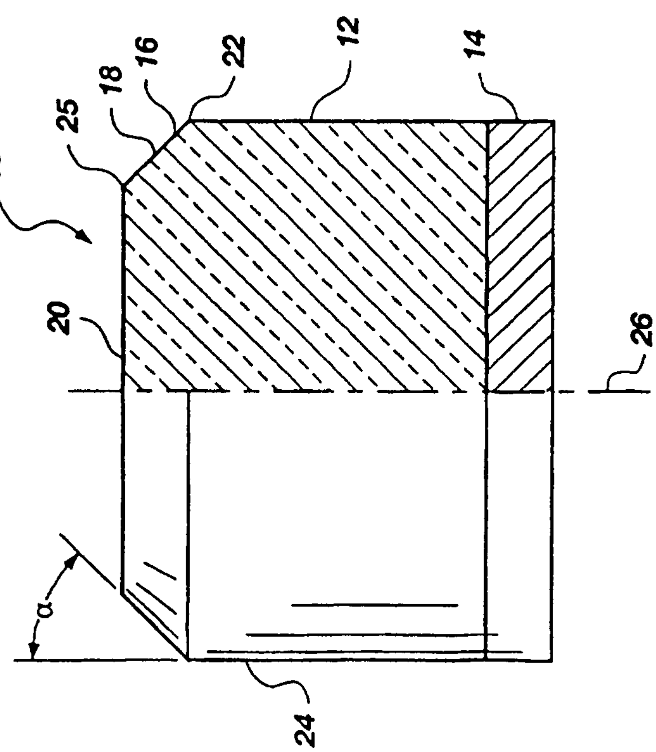

Fig. 1A

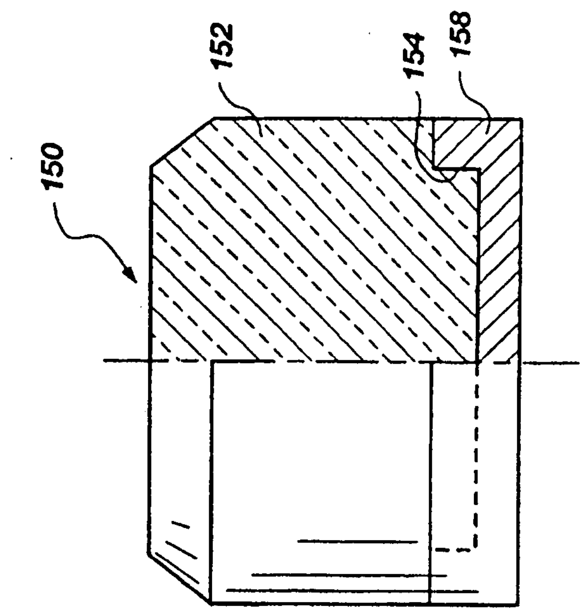

Fig. 2A

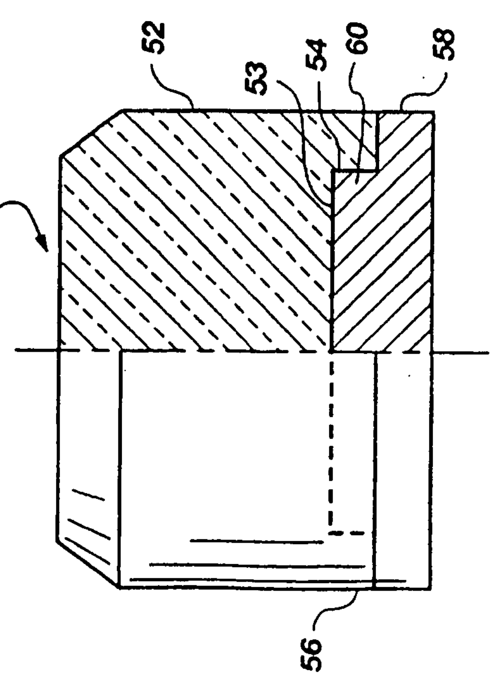

Fig. 2

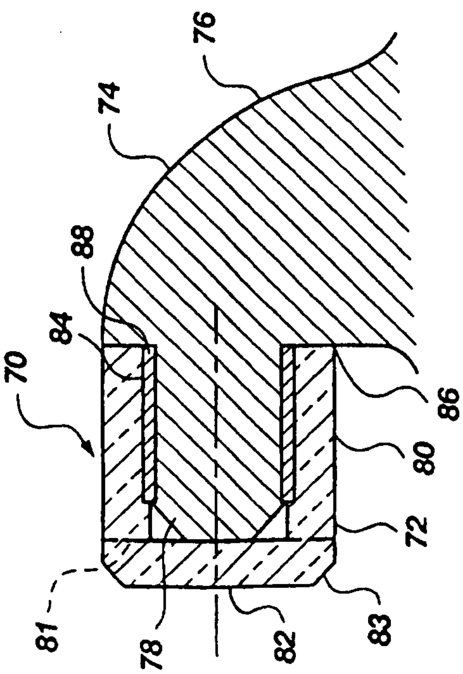

Fig. 3

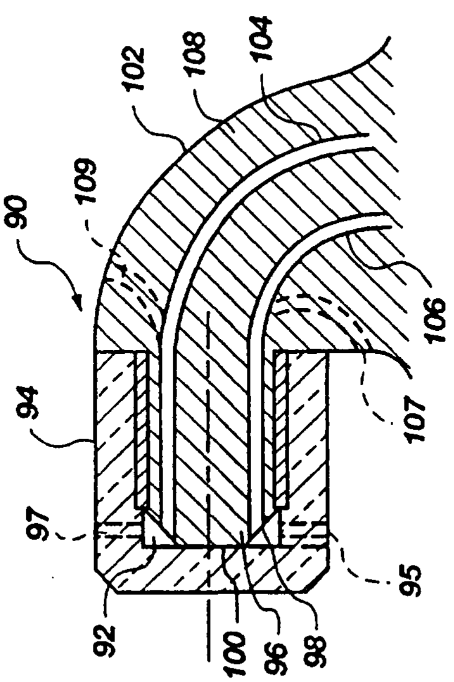

Fig. 4

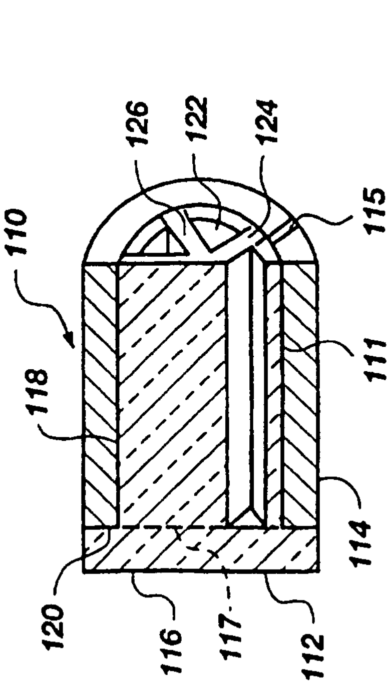

Fig. 5

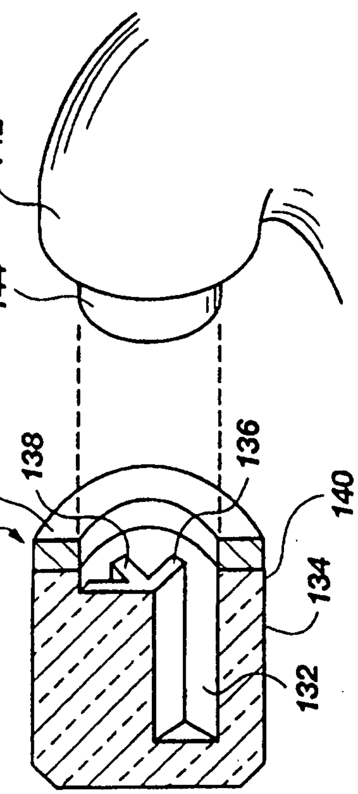

Fig. 6

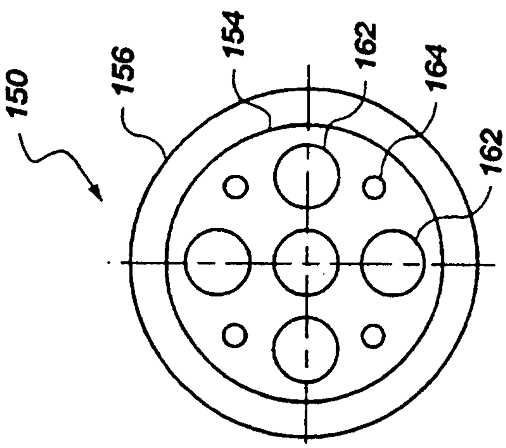

Fig. 8

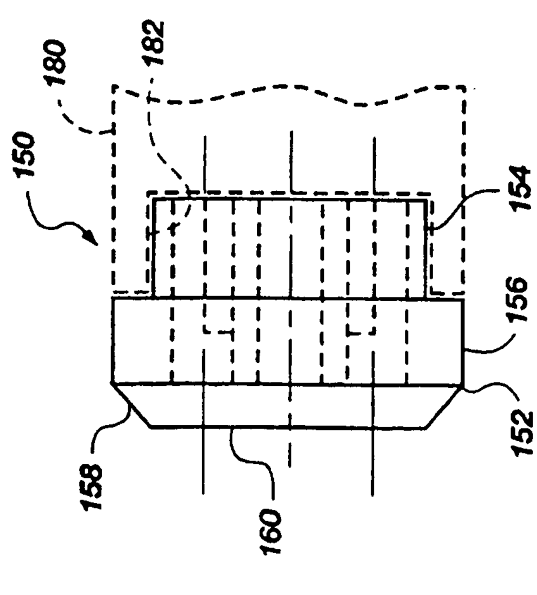

Fig. 7

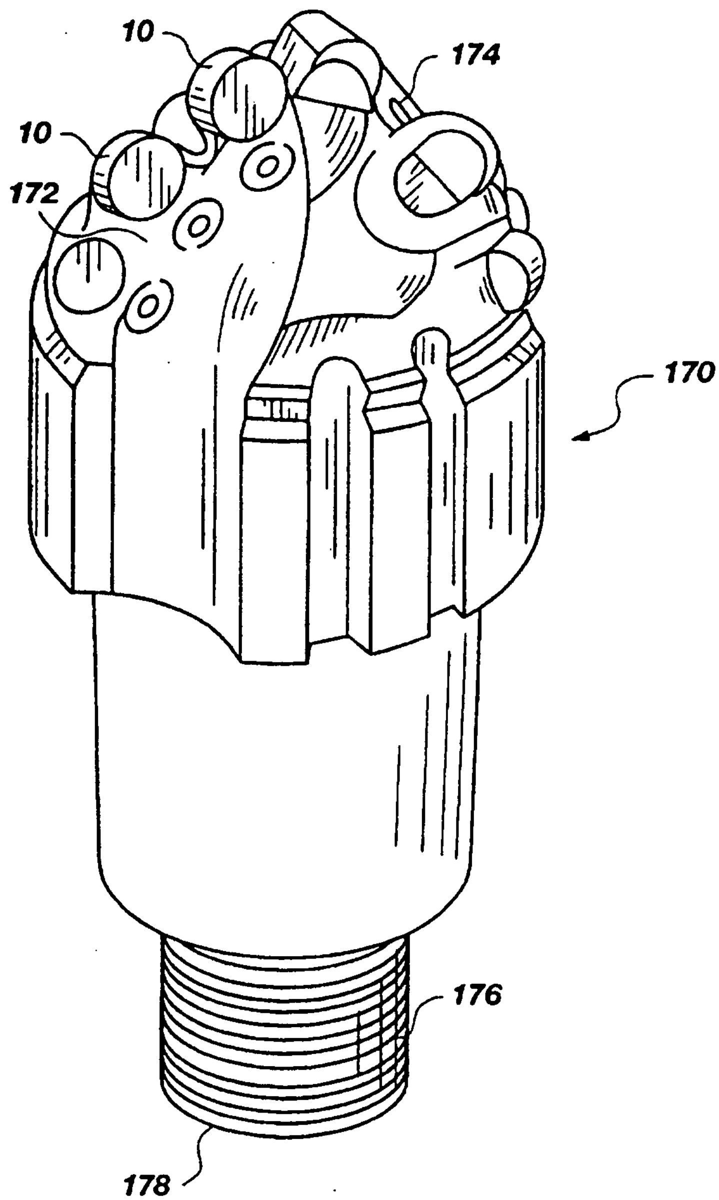

Fig. 9